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New Concepts for U.S. Combat Vehicle Systems

W. J. Whelan.

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This publication describes a research effort which examined a new approach for developing land combat vehicle systems. The research focused specifically on new tank systems. The report begins with a summary of the asserted needs for significant increases in the capabilities of current combat vehicle systems. Next, a generic concept development approach based on the idea of distributed vehicle systems with unmanned subsystems is described and related to R&D challenges. The approach is used to generate a distributed tank concept, TEARS (Tank Effectiveness Augmentation by Remote Subsystems). The TEARS concept is explored from several aspects, including combat engagement capabilities, technological feasibility, and affordability. Last, a TEARS technology development and demonstration program is outlined.

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New Concepts for U.S. Combat Vehicle Systems

W. J. Whelan

December 1982

Prepared for
The Defense Advanced Research Projects Agency



PREFACE

Begin { This report documents Rand research on a new approach to developing concepts for U.S. land combat vehicle systems and capabilities. } The effort was sponsored and funded by the Defense Advanced Research Projects Agency (DARPA) and by The Rand Corporation with its own research funds. The material was originally organized as a briefing. Many of the illustrations duplicate the briefing slides; the text has been expanded to reflect questions raised by various audiences.

{ The approach was used to generate a new ~~tank~~ ^{armor} system concept involving current tank systems. This tank concept, which is called TEARS (Tank Effectiveness Augmentation by Remote Subsystems), is based on augmenting a current tank with detached, unmanned, highly automated, tank-crew-managed target acquisition and engagement subsystems. The approach should be helpful ~~in addition~~ ^{for} for creating new designs and operational concepts for future tank systems. } *END*

An examination of the TEARS concept was conducted which emphasized its relevance to postulated central NATO-Warsaw Pact conflicts. The overall results of the research effort were used to help formulate a proposed DARPA/U.S. Army technology development and demonstration program for exploring the feasibility of TEARS.

SUMMARY

A new approach for developing ground combat vehicle systems concepts based on the use of unmanned, highly automated, and remotely managed target acquisition and engagement subsystems offers the potential for major increases in system firepower, firepower mobility, and survivability. The approach can be used to extend the capabilities of current tank systems and to provide alternative designs and operational concepts for future tank systems.

Recent overall advances and specific successful experiments in on-vehicle microcomputer data collection and control, integrated IR-radar sensors, and various missile homing technologies suggest the near-term feasibility of highly automated, remotely managed engagement subsystems. A concept to augment current tank systems with such subsystems has been conceived and studied at Rand. This concept, named TEARS (Tank Effectiveness Augmentation by Remote Subsystems), extends the capabilities of current tank systems by employing tank-crew-managed, highly automated, lightweight, limited mobility platforms (Demons) equipped with IR-radar sensors and antiarmor weapons. The TEARS system concept appears to offer force multiplier improvements to tank systems and forces in terms of selected engagement-related capabilities and intra- and inter-theater mobility.

Careful design and selective employment of Demons would allow the augmented tank to lose little, if any, of its current capabilities. Further, the knowledge acquired in developing TEARS and Demon could be invaluable for generating alternative designs and operational concepts for future tank systems.

Initial analyses related to the engagement effectiveness, feasibility, and affordability of the TEARS concept point out the need for an explicit, focused, and integrated technology development and demonstration program.

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I. INTRODUCTION

Aerospace Daily, William E. Colby, 10/12/79, p. 205.

Because the Soviets have more tanks...does not mean that we need to produce an equal number. Rather, we need to produce the appropriate counteraction to frustrate that particular weapon system....

We do not need to have an equivalent number of tanks, but we do need the force readiness, the intelligence machinery, the precision guided munitions, the logistics backup and the electronic warfare capabilities in Western Europe to ensure that the Soviet tank force would be stopped in its tracks....

Tank Warfare, Richard Simpkin, 1979, p. 108, Brassey's Publishers Limited: London.

One may however question whether it makes sense to pack more and more technical and logistic resources--and most of all more supporting manpower--behind a single tank which can be knocked out by a single shot.

This publication describes a Rand research effort sponsored and funded by the Defense Advanced Research Projects Agency (DARPA) and The Rand Corporation with Rand research funds. The effort examined a new approach to developing concepts for tactical land combat vehicle systems and focused specifically on tank systems. The purpose of the study was to explore potential advantages inherent to this approach, develop concept statements for tank systems using this approach, and identify technologies required for concept feasibility demonstrations. Because the approach appears to be useful over a broad range of land combat vehicle systems, it is considered a "generic" approach.

The research began at Rand in early 1978 and was proposed to DARPA for concept development support in late 1978. Initial funding was provided under the DARPA New Ideas Council and the contract began in January 1979. DARPA funding was used to continue the research through FY 80 and early FY 81. Rand Sponsored Research funding took over for the latter part of FY 81. A previous Rand report (Ref. 1) summarizes the research through FY 80.

The research was a direct outgrowth of previous Rand studies sponsored by DARPA. Four noteworthy precedents were: the distributed area weapon systems concepts investigated by M. G. Weiner, E. W. Paxson, and R. A. Wise in the early and mid-1970s (Refs. 2,3), the engagement analyses performed by the same Rand group for the U.S. Army V Corps staff in 1977-78, the studies of battlefield regeneration of combat vehicles within the recent DARPA-sponsored Rand land vehicle maintenance project, and the design guidance analyses of microcomputer-based vehicle monitoring systems completed by the same maintenance project (Refs. 4,5).

The work by Weiner et al. explored the interactions between technical characteristics and tactical uses for various postulated distributed area weapons systems and created an analytical methodology for investigating innovative tactical weapons systems. The V Corps engagement analyses considered direct fire weapons systems capabilities of battalion-size units in forward defense positions. The results of these force-on-force analyses implied the need for greater and more coordinated direct firepower and firepower mobility for combat vehicle systems. The combat vehicle regeneration studies reinforced the oft-

stated need for significant increases in combat vehicle survivability and rapid reinforcement/replacement capabilities. The vehicle monitoring system research showed the feasibility and potential of using on-vehicle microcomputers for automated management of combat vehicle subsystems.

This report begins with a brief review of some of the hypotheses on the need for significant increases in the capabilities of current combat vehicle systems. This need is cast in terms of corresponding R&D challenges. Next, a generic approach based on the idea of distributed combat vehicle systems and the use of unmanned subsystems is described and related to the R&D challenges. The approach is discussed further in terms of a specific distributed tank system concept, TEARS. The TEARS concept is examined from several aspects including combat engagement capabilities, technological feasibility, and affordability. Last, a TEARS technology development and demonstration program is outlined.

The research summarized in this report represents the combined efforts of a Rand project team composed of C. R. Harz, J. R. Lind, E. W. Paxson, R. G. Salter, and the author.

II. BACKGROUND

Combat vehicle systems, particularly tank systems, are the nuclei of both NATO and Warsaw Pact ground warfare forces. These systems are critical to the offensive, defensive, and counteroffensive strategies and capabilities of both alliances. Indeed, respective tank system inventories are often noted and emphasized (in qualitative as well as quantitative measures) in comparing overall military strengths and defense investment policies. Both the United States and the USSR have taken steps to insure large inventories of modern combat vehicle systems, and large fractions of their defense budgets are dedicated to the development, production, and operational support of combat vehicle systems and antiarmor systems.

The Soviet Army has a considerably larger inventory of combat vehicle systems than does the U.S. Army and apparently intends to maintain its numerical superiority. In addition, recent estimates of the battlefield effectiveness of newer Soviet combat vehicle systems suggest that the United States can no longer claim superiority in this area. The simple numerical superiority of Soviet combat vehicle systems can be misleading when stated in terms of gross inventory ratios, since Soviet concentration of forces can lead to a superiority in areas of a NATO front that exceeds inventory ratios by factors of two or three, as schematized in Fig. 1.

The contributions of combat vehicle systems to ground warfare have been vividly evident in several wars and examined in many studies. The evolution of these systems since their introduction has been recorded in



Fig. 1 — NATO vs. Warsaw Pact tank forces

considerable detail and displayed pictorially in many volumes. Tank systems, in particular, have a well-established and well-known evolutionary pattern. The basic attributes of this paradigm, i.e., the tank system as a crewed, armored, heavy tracked vehicle with one main weapon, is illustrated by various tank silhouettes in Fig. 2. The tank system paradigm should not be surprising, however, since the roles and missions of tank systems have not varied much since their introduction in World War I, more than 65 years ago. Also, no design influences such as threats, costs, manpower, or materials have been significant enough to force tank designs and operational concepts out of the paradigm's dimensions. However, current and developing antiarmor weapon threats as well as trends in antiarmor systems and forces are severe enough (for even the newer tank systems) to suggest rethinking the character and capabilities of tank systems and operations. Future generations of tank

systems that are developed and used within the confines of the paradigm will have great difficulties in meeting the increasing demands for effectiveness, survivability, and efficient manpower utilization.

Some well-known and often studied limitations of current U.S. combat vehicle systems and forces discussed next are emphasized to point out increased or new capabilities required or desired for these systems.

A DARPA-supported engagement analysis of the defensive capabilities of a forward-deployed covering force of the U.S. Army V Corps was conducted during 1977-78. NATO-Warsaw Pact Central European conventional conflict scenarios were used to establish the analysis conditions. These typical scenarios included an in-place and outnumbered U.S. force defending against an attacking, armor-rich Soviet force. The analytical results indicated that target engagement or servicing opportunities for the defending U.S. forces were more plentiful than could be met with their available weapons systems--

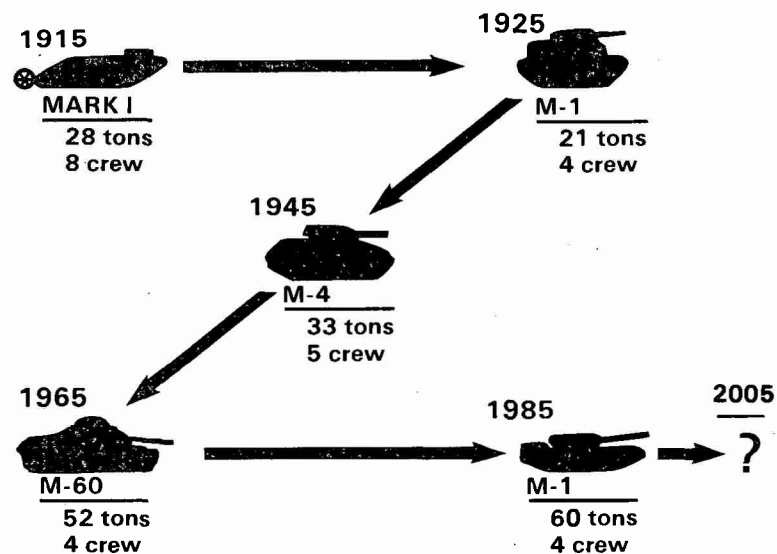


Fig. 2 — Short history of tank systems

suggesting the need for additional direct fire capabilities.

These same results also lead to the inferences that outnumbered defenders must (1) coordinate their weapons systems efficiently for high effectiveness and (2) more aggressively pursue target servicing under conditions of limited visibility (poor weather, night, smoke, etc.) than under good visibility. The defending force has less time (or range) under poor visibility conditions to accomplish the same attrition levels of enemy forces that can be achieved under good visibility conditions. The engagement analysis results in addition reinforced the need for increased capabilities in direct fire engagements of targets at longer ranges and in higher target servicing rates at shorter ranges.

Proposed new measures to implement the current NATO strategy and other power projection strategies often imply the need to upgrade the basic capabilities of NATO combat vehicle systems. Sizable increases in the firepower-manpower ratios of combat vehicle systems appear particularly desirable from several aspects (fewer systems to buy, deploy, and maintain as well as fewer crews to organize, train, and support).

Improvements in the U.S. ability to rapidly project effective ground combat power are sorely needed but depend directly on the inter-theater, intra-theater, and cross-battlefield movability (size, weight, and mobility characteristics) of combat vehicle systems. It is difficult to see how major improvements in all these areas can be made within the current combat vehicle design paradigms.

The spectre of nuclear/biological/chemical (NBC) warfare in a NATO-Warsaw Pact conflict continues to be raised as the capabilities and

intentions of Warsaw Pact forces become better known and assessed. Our present vulnerability to NBC weapons needs to be reduced and, correspondingly, our capability to fight more effectively in NBC environments raised. Combat vehicle systems can make unique contributions in NBC warfare to the extent that crews are protected from casualty agents and equipment is immune to material agents. The present concepts of providing tank crew members with personal and/or compartment protection do not permit sustained operations.

Studies of the regeneration of damaged or failed U.S. combat vehicle systems under battlefield conditions, particularly within high intensity Central European conventional conflict scenarios, raise additional questions. The estimated high initial attrition (first few battles or days of battle) for NATO combat vehicle systems can have a serious to critical impact on the outcome of the conflict. Ways must be found to drastically reduce this expected high initial attrition of combat vehicle systems. Systems lost in the early battles or days of a conflict could well have a higher value than those lost later in terms of opportunities to destroy Warsaw Pact forces or slow their momentum. If NATO forces are to defeat concentrated Warsaw Pact forces attempting breakthroughs, more rapid ways of reinforcing and replacing combat vehicle systems must be found to provide sufficient firepower to bolster weakened defensive forces.

The U.S. incapacity to move large numbers of tank systems rapidly over inter- or intra-theater distances could seriously jeopardize effective responses to developing and ongoing conflicts. Current tank systems are too heavy to be delivered quickly in large numbers over long distances by the present U.S. airlift fleet. In addition, tank systems

are dependent on their own mobility or tank transporters for intra-theater movements. Long road marches strain current tank systems and may be too slow to meet many tactical situation requirements. Tank transporters are in short supply, restricted to travel over road networks, and may be too slow to counter unexpected or rapidly developing changes in tactical situations.

The dramatic rise in procurement costs for the present generation of U.S. tank and other armored combat vehicle systems, along with their required manpower needs, may prohibit matching the Soviet buildup. These factors also emphasize the need to increase the survivability of individual systems.

Continuation of current trends presages problems for future combat vehicle systems. The basic survivability of these systems will be severely challenged as more and more platforms on the tactical battlefield mount antiarmor weapons. Antiarmor capabilities could reach such proportions that the cost in dollars or resources of protecting combat vehicle systems could become prohibitive. The basic character of combat vehicle systems might have to change to insure their survivability and effectiveness in future armor-antiarmor battles. The long standing trend typified by the slogan "another weapons system, another crew" may have to be modified. Rapid multiplication of battle capabilities of vehicle systems and forces without corresponding increases in numbers of crews is highly desirable and could be critical in future wars.

III. RESEARCH AND DEVELOPMENT CHALLENGES

The serious near and far term problems of U.S. combat vehicle systems generate clear and difficult R&D challenges. R&D near term efforts must lead to systems with significant increases in firepower, firepower mobility, and survivability, while working with a combat vehicle force already designed and deployed. In addition, the appropriate R&D communities should search for new alternatives to the classical combat vehicle system designs, i.e., the paradigms. Feasible alternative designs should exist by the time another generation of combat vehicle systems is considered for production and deployment.

The United States is, of course, developing a wide variety of antiarmor systems to counter Soviet armor forces. Many of these developments are promising, and those which finally enter the inventory will help to decrease the stress on the U.S. combat vehicle force-- but probably not enough. Some of the R&D efforts to improve the armament, armor, and mobility of combat vehicle systems will also be valuable but are unlikely to provide U.S. systems with decisive edges in combat with Warsaw Pact armored forces. The main R&D theme continues to be to try to squeeze more capabilities from the classical paradigms. The development of combat vehicle systems has been evolutionary although the need for revolutionary approaches, i.e., for new paradigms, is becoming clearer and clearer.

One way to change the current combat vehicle system paradigm is to distribute the basic functions among separated but interrelated subsystems. Target acquisition and engagement subsystems could, for

example, be remotely located but commanded from the manned subsystem. In this case the tank "system" would consist of a number of subsystems not collocated in a single vehicle but placed in separate vehicles. Functions would be performed by subsystems acting singularly or in concert. System capabilities would be achieved by using advanced automation technologies, remote management techniques, and new tactical employment options.

The idea of the distributed vehicle system suggests a sequential R&D approach. For the near term period (defined in terms of the lifetime of the current and programmed combat vehicle system inventory), unmanned and dispersed subsystems could augment current vehicle systems. For the far term period (the next generation of combat vehicle systems), new designs and operational concepts could be developed based on the use of unmanned and dispersed subsystems. How to design and employ such far term systems, however, is not yet known. The development and deployment of unmanned subsystems which augment current combat vehicles would provide the basic knowledge for the design of far term systems.

IV. DISTRIBUTED COMBAT VEHICLE SYSTEMS

A distributed combat vehicle system is an array or network of unmanned, interconnected (by data links), mobile target acquisition and engagement subsystems managed by a mobile manned command center. Each distributed system with its multiple subsystems would have more firepower and survivability than the current, nondistributed combat vehicle system. The actual increases in capabilities, however, depends on overall system design and employment. These subsystems would multiply force effectiveness and firepower-manpower ratios. The firepower-manpower ratio could be variable, i.e., depend on the number of unmanned subsystems coupled to a single manned management center. A single distributed vehicle system might provide more coordinated firepower than an equivalent number of single vehicle systems. An array or network configuration also provides some unique firepower mobility and survivability properties.

A single command center or set of command centers could provide desired or needed rates of fire by moving and coordinating the fire of several subsystems. Lightweight subsystems could be moved rapidly cross-battlefield and intra- or inter-theater distances by higher speed ground transports, cargo aircraft, and helicopters. Firepower mobility would thus be achieved by rapidly moving subsystems to link up with prepositioned command centers.

A new dimension in functional survivability would be achieved by presenting enemy weapons systems with a dispersed target array. System vulnerability could be reduced further by interconnections among command centers.

Several major questions arise in comparing distributed combat vehicle systems with nondistributed or single vehicle (point) systems. The graphic displays in Fig. 3 suggest these questions by referring to comparisons of notionally distributed (D) and nondistributed (P) systems of approximately equal costs in defensive roles.

Figure 3a hypothesizes the relative insensitivity of the functional survivability of distributed combat vehicle systems to increases in attacker to defender force ratios. The surviving force metric is actually a measure of the number of surviving system crews. Their survivability might be much greater with distributed systems since the battle is fought by remote subsystems. Also, battle force commanders, who often know only a range within which actual force ratios lie, would benefit by forces that are less sensitive than current forces to force ratio uncertainties.

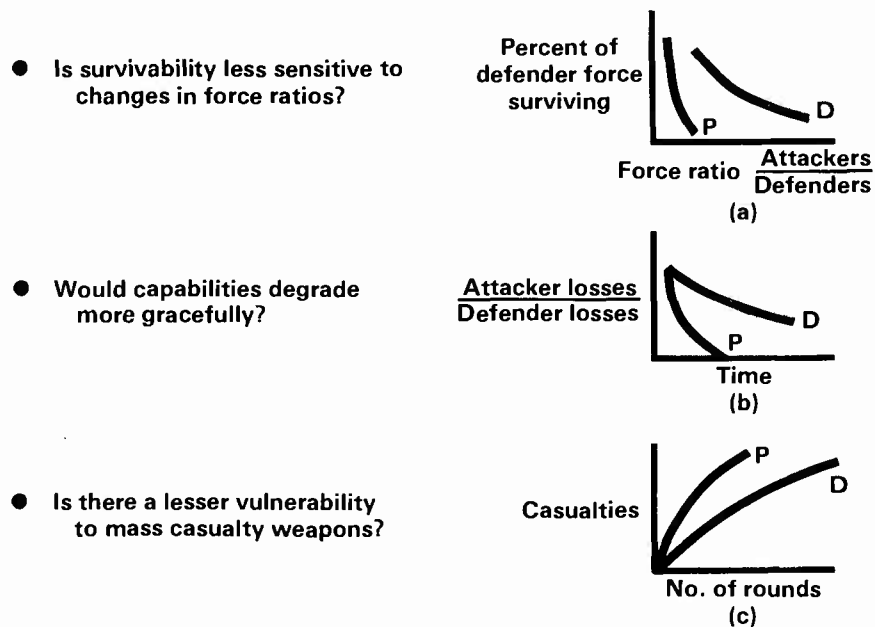


Fig. 3 — Some potential advantages of distributed combat vehicle systems (D) vs. point systems (P)

A frequently heard request from battle force commanders is for forces whose capabilities will degrade gradually, not catastrophically, and allow sufficient time for tactical decisions and force movements. Distributed systems may degrade more gracefully than point systems. Fig. 3b hypothesizes the variation of the attacker to defender loss ratio over battle time for distributed (D) and nondistributed (P) system forces. Defending forces clearly need to keep this ratio in their favor long enough to discourage or destroy attacking forces.

If its systems are distributed and unmanned, a force could be less vulnerable to mass or casualty weapons such as conventional artillery, nuclear, or chemical weapons (Fig. 3c). Conversely, the attacking force has to expend far more casualty munitions to achieve the same level of damage against distributed systems as against nondistributed systems.

Although these generic characteristics of distributed combat vehicle systems can be readily hypothesized and their relationships displayed, other characteristics are neither as obvious nor as easily represented. Distributed vehicle systems have, in general, not been subjected to enough study or experimentation to test such hypotheses.

V. TANK EFFECTIVENESS AUGMENTATION BY REMOTE SUBSYSTEMS (TEARS)

We conceived a near term distributed combat vehicle system based on the current tank system and used it to focus our research efforts. The system, named TEARS (Tank Effectiveness Augmentation by Remote Subsystems), is illustrated in Fig. 4.

The TEARS concept pictures a current tank augmented or supplemented with one or more unmanned, highly automated target acquisition and engagement subsystems. These unique subsystems have been named Demons[1] and consist of a mobile or movable platform with sensor, weapon, and command modules.

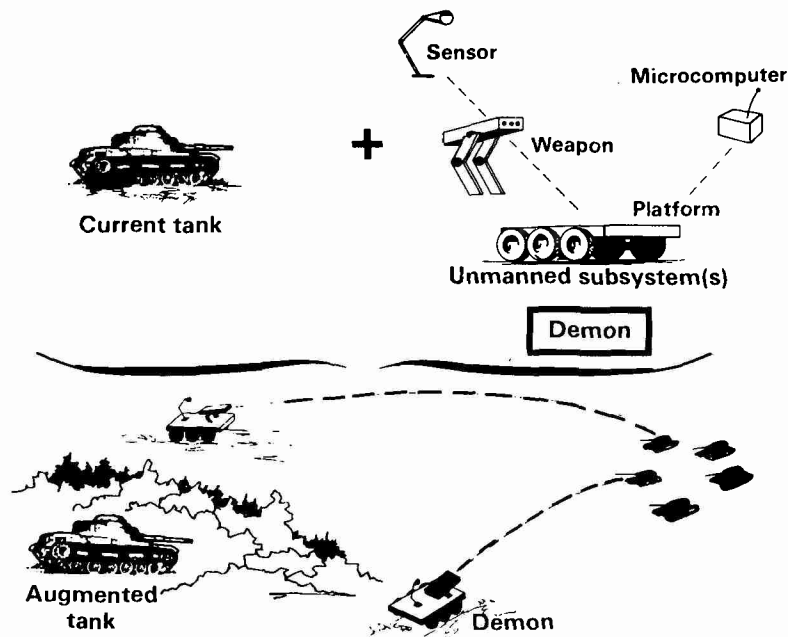


Fig. 4 — TEARS concept

[1] So named because in many cultures a demon is a disembodied human spirit lying in wait to snare an unsuspecting traveler--exactly what our Demon should do.

A set of development criteria was established (Fig. 5) to help develop, characterize, and analyze the TEARS concept. These criteria create a specific direction or approach for developing a distributed tank system concept. Different criteria and different approaches could be used and should be considered in any further investigations.

The basic idea of TEARS is to complement the effectiveness of the firepower, firepower mobility, and survivability of the current tank system. The basic criterion for the concept is that the augmented tank be unencumbered to perform its basic missions. Any modifications of the tank or additional demands on its crew must be minimal. This criterion implies that a Demon be autonomous, i.e., require little attention from the tank crew. The tank crew would operate in one of two exclusive modes--managing the Demon(s) or operating the tank. The tank is either a tank or a command center but not both simultaneously. Thus, multiple

- **Augmented tank**
 - **Minimum interference with tank design, configuration, and operations within basic mission**
- **Demon**
 - **Extend tank capabilities***
 - **Operate under tank crew management or autonomously**
 - **Have limited armor protection**
 - **Be easily moved cross-battlefield distances**
 - **Have short distance self-mobility**
 - **Cost fraction of tank costs**

***Other approaches to approximate augmented tank capabilities have not been explored**

Fig. 5 — TEARS concept criteria

operating modes are needed for TEARS to both preserve and then increase the basic capabilities of the current tank. This idea leads to the most significant design criterion for Demon, i.e., that it have two operating modes: (1) managed by the tank crew and (2) totally autonomous.

The Demon in the the TEARS idea is conceived as a remotely managed or commanded subsystem, but not as a remotely controlled subsystem.[2] The Demon would have to be highly automated, i.e., capable of collecting and analyzing information from its own sensors, receiving commands, and planning and executing all required actions. Selected significant decisions would be left to the tank crew, e.g., weapon launch permission, when the Demon is in the commanded mode.

Demons would extend the basic capabilities of current tank systems and help reduce some of the earlier mentioned problems facing tank forces. The target servicing capabilities of tank systems could be increased by using Demons with longer range, higher rate of fire weapons and multispectrum sensor modules. Easily moved Demons would provide greater firepower mobility for tank forces over cross-battlefield as well as intra-theater distances. The functional survivability of tank systems would be raised in proportion to the number of Demons in each TEARS system.

Other general criteria for Demons include (1) basic design protection such as armor and, possibly, self-mobility to further increase survivability and provide local positioning capabilities, and (2) low procurement and support costs to permit large inventories.

[2] Remote management or command implies the use of highly automated subsystems that can integrate all required functions into a nearly autonomous operational mode. The remote manager would interface with the subsystem only in the case of major decisions.

Although reduction of these criteria to broad design guidance has been accomplished in part by our study effort, a well-planned combined study and experimentation program is needed to develop comprehensive design criteria and establish more detailed design guidelines.

The purpose of Demons is to destroy enemy combat vehicles. Since Demons are expendable, without crew loss, their designs should be consistent with their intended purpose and estimated lifetimes, i.e., within appropriate cost and performance envelopes. A Demon should not cost more than a fraction of the cost of the augmented tank.

Several aspects of the TEARS system concept have been considered to illustrate capabilities, to help formulate and understand criteria and design guidance, and to set the stage for subsequent analyses. TEARS deployment and employment are shown in Figs. 6 and 7.

Demons could be stored during peacetime in CONUS or theater depots, in Corps or Division rear areas, or deployed with tank units. Storage and shipping containers would hold one, perhaps two, Demons and the necessary instrumentation or instrumentation interfaces to allow easy and accurate readiness checks. These containers would be transported by inter- and intra-theater aircraft, lightweight ground transport, and utility helicopters (Fig. 6).

The utility helicopter transport criteria (for rapid deployment from forward storage locations to battle areas or over cross-battlefield distances) suggests a Demon within the weight range of one to three tons. A large number of Demons could be carried by long haul inter-theater aircraft (C-141 and C-5 type), particularly if the aircraft and the Demons are designed so that the Demons can be double stacked. For example, for a typical CONUS to Europe range payload a C-5 could

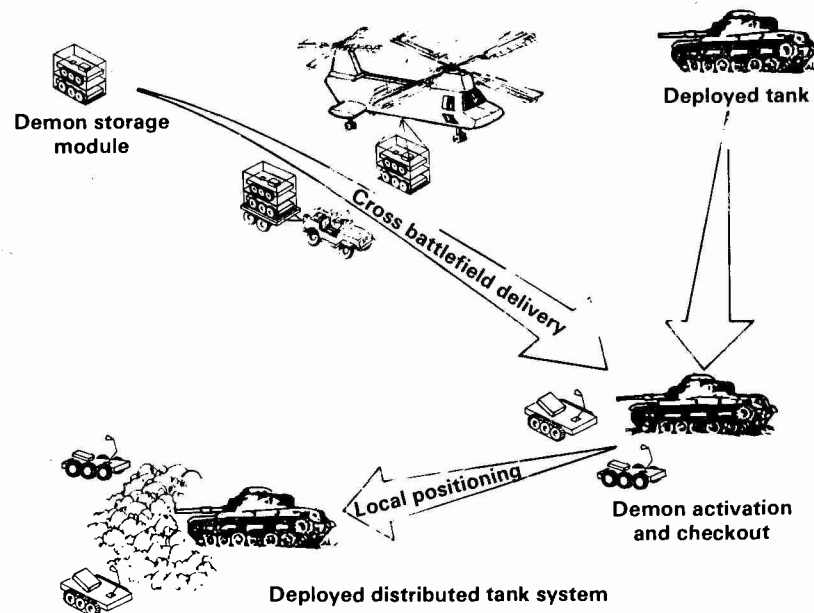


Fig. 6 — TEARS deployment

probably carry some 25 to 50 Demons (Ref. 6); intra-theater aircraft (C-141 type) could carry approximately 7 to 15 Demons; and Army utility helicopters (CH-60, Blackhawk type) could each carry a Demon container (one or two Demons).

A TEARS system would be activated after delivery of Demons to a deployed tank unit and the assignment of Demons to specific tanks. The TEARS systems would be checked for proper operation and then moved into tactical positions by crews that had adequate pretraining in the use of Demons under combat-like conditions.

Early Demon designs should be considered in the context of augmenting tanks in defensive operations with only limited capabilities for offensive actions. However, to the extent that Demons free tanks for highly mobile defensive operations and enhance their survivability for offensive actions, they contribute to the overall effectiveness of

tank forces. Later Demons, with greater mobility, could aid various specific offensive tank operations, particularly the high risk operations--crossing of rivers or minefields.

Demons could provide large increases in the fields of view and fire controlled by a single tank system, thus allowing greater dispersal or concentration of tank force firepower. Classical tank tactics may be substantially altered by the use of Demons, a possibility that points up the need for the development of operational concepts for augmented tank systems.

Two modes of target engagement have been considered for a deployed TEARS system, as shown in Fig. 7. For longer range engagements (3 to 5 km), Demons would operate under tank crew management. In this TEARS mode the augmented tank would use cover and concealment to minimize its signatures and engage oncoming enemy combat vehicles with Demon weapons. If enemy armor systems closed to shorter ranges (about 1 km), the augmented tank could exercise one of several options. It could switch the Demons to total autonomy and enter the battle as an unencumbered tank, or it could move to an alternative position, leaving the Demons to defend the vacated position or call for more Demons as replacements or reinforcements. A TEARS system would provide tank forces with new tactical employment options.

There are many different ways to configure Demons with sensor, weapon, and command modules to perform these modes of engagement. For illustration, a particular Demon was configured. The Demon sensor module is conceived to contain integrated radar-IR sensors, operated by the on-board microcomputer. The microcomputer also controls the module of IR homing missiles. The activated sensor module scans for targets

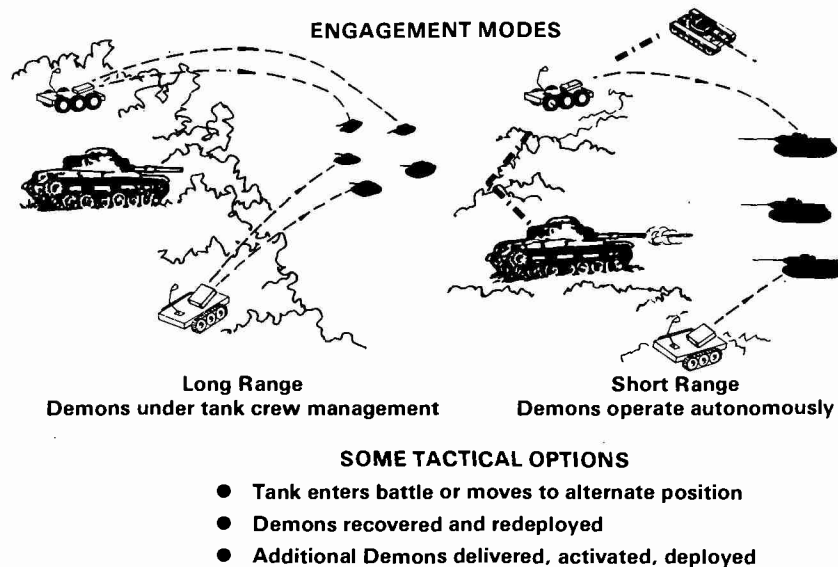


Fig. 7 — TEARS employment

using either radar and IR sensors or both (depending on its programming or instructions from the tank crew). Prospective targets are subjected to classification and identification routines stored in the microcomputer. Selected targets are processed in terms of fire control data (target azimuth and range) and missiles are designated, activated, and checked. When fire control activities are completed, the tank crew is notified and provided a target image. Missile launch occurs only with crew assent. The entire process of target surveillance, tracking, identification, weapon selection, and readiness and fire control would be performed automatically by the Demon according to prestored programs. The tank crew burden would be limited to making the missile launch decision. The missile trajectory would be calculated from appropriate target range and azimuth information and would place the missile IR homing warhead in its proper target seeking envelope.

The radar component of the sensor module would provide primary range and azimuth data for fire control (supplemented, if necessary, by IR data).

For targets at closer ranges, missile IR homing sensors would be activated while missiles were still in their launchers. This early activation step would allow the missile homing system to achieve target lock-on before launch and the Demon to have high firing rates (salvo or ripple fire). Appropriate algorithms would control targeting and firing events to prevent or insure multiple firings per target.

Identification friend or foe (IFF) problems would arise quickly in battle environments, particularly with the Demons operating autonomously. Several possibilities are raised by this problem--the use of unique radar or IR signatures for friendly vehicles, limited fire sectors for Demons, and so forth. This problem may be critical to the use of automated target engagement systems and deserves considerable attention in further studies.

Figure 8 lists advantages that accrue to tanks through Demon augmentation. Tank crews, for example, would have more knowledge and control of offset supporting and flanking weapons. The current tank would gain a longer range weapon (the Demon's missiles) without any of the well-known problems of reconfiguring the tank or its gun system.

The major operational issues regarding the utility, feasibility, and affordability of distributed combat vehicle systems will require extensive study and experimentation. Some important questions are indicated in Fig. 9. We were able to consider only selected subissues within the time and resources available to our study effort. The TEARS concept was employed to focus relevant analytical efforts and to provide estimates of system technical characteristics and operational

- **Provide wider and longer fields of view and fire by Demon positioning and movement**
- **Provide tank crew with control over offset supporting and flanking weapons**
- **Provide tank with missile capability without reconfiguration of tank**
- **Increase tank mobile defense role by using Demons as static defense systems**

Fig. 8 — Other advantages of TEARS

- **Could remote, unmanned subsystems make a major difference?**
 - **What capabilities really count?**
- **Are these concepts feasible?**
 - **Where is the needed technology?**
- **Can we afford it?**
 - **What factors will drive costs?**

Fig. 9 — Major questions for current research

Can unmanned, remotely managed, automated target acquisition and engagement subsystems (Demons) increase the battlefield effectiveness of current combat vehicle systems and forces? The answer to this question can be approached by exploring the advantages which an augmented tank system concept, TEARS, might have over present tank systems in hypothetical engagements. This exploration also aids concept development by forcing consideration of certain questions, e.g., what capabilities would be really significant for an augmented tank system. Since the augmented engagement capabilities of a TEARS system reside largely in its Demons, and tank capabilities have been extensively studied, our exploration has been concerned primarily with Demon characteristics and capabilities. A deliberate effort was made to find and describe those Demon capabilities that would seem to provide major increases in simulated engagement effectiveness of current systems.

Determination of feasibility for a near term distributed combat vehicle system, such as TEARS, must consider all the issues relevant to the technologies needed for the desired system. First, for a stated set of TEARS or Demon capabilities a corresponding (but not unique) set of system technical characteristics can be identified. Second, the feasibility of these characteristics can be largely determined by finding and assessing required technologies. Third, the integration of required sensor, weapon, and management technologies can be resolved by more extensive study and a program of selected experiments.

The affordability question, which must await the development of specific system designs and operational concepts for resolution, can be addressed at least two ways in early concept development. First, as

already suggested, hypothetical system capabilities and derived supportive technologies can be used to provide a basis for estimating major cost factors. Second, TEARS or Demons can be compared with current or planned weapons systems which perform similar roles.

The general analytical approach for exploring TEARS engagement effectiveness and related system capabilities is displayed in Fig. 10a. A DARPA-sponsored, Rand-developed analytical methodology, MAGIC (Manually Aided Gaming of Integrated Combat) (Ref. 3) was adapted to serve as the primary exploratory tool. The MAGIC methodology is a computer-aided, terrain-board-assisted, two-sided force-on-force manual game. MAGIC was specifically developed to study innovative tactical warfare systems in terms of technical characteristics-tactical use interactions and to expose implications for system design and operations. Various engagement-related capabilities (target acquisition ranges, weapon delivery ranges, firing rates, etc.) were postulated for Demon and used as inputs to a subroutine of the MAGIC methodology. The results provided an understanding of the influences of various engagement parameters and helped to develop meaningful engagement success measures. These measures aided in selecting significant postulated capabilities and directing technology assessments. The assessments, in turn, suggested refinements or redefinitions in Demon's postulated capabilities. This process was repeated until a set of Demon capabilities was obtained which indicated significant and, it is hoped, realistic increases in tank system engagement effectiveness.

The analytical approach is shown in greater detail in Fig. 10b. The scenario selected for the TEARS capability analysis was based on a central NATO front location and a reinforced Soviet regiment attacking a

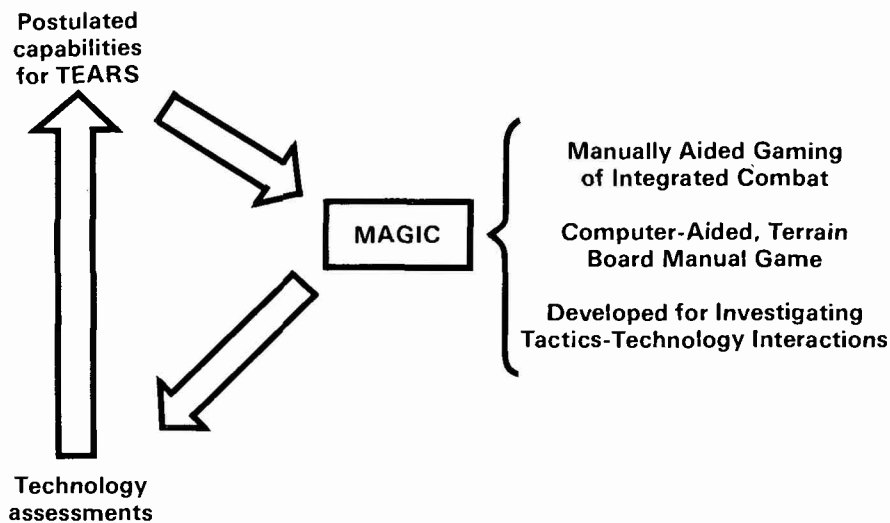


Fig. 10a — TEARS capability analysis methodology

U.S. battalion-size armor unit. Probable U.S. weapon positions and anticipated Soviet routes and rates of advance for this scenario were based on information from the U.S. Army V Corps staff. Weapon positions and attack routes were inputs to a MAGIC subroutine, TIMER (terrain intervisibility and movement evaluation routine) (Ref. 7). TIMER outputs were used to establish firing or target servicing opportunities for both U.S. and Soviet weapons systems. These target servicing opportunities were derived from objective terrain and weapon reaction time data and became inputs to another MAGIC subroutine, VISOR (visible strike opportunity recorder) (Ref. 8). VISOR is a two-sided, force-on-force engagement simulation which requires a variety of subjective inputs (detection, hit and kill probabilities, firing doctrines, etc.). VISOR produces expected kills of U.S. and Soviet combat vehicle systems and a host of related information (identification of killed and killing

systems, times of fire and kill, number of rounds fired) useful for developing engagement success measures. Some of the success measures developed and used included kill ratios, kills per system per kilometer of advance, and kills per minute of engagement. These measures were used to score selected sets of Demon capabilities and to provide a basis for directing technology assessments. The completed assessments led to more realistic definitions of Demon capabilities.

Our analyses were based on using Demons to provide current tank systems with increased engagement range and firing rate capabilities across a spectrum of atmospheric (haze, smoke) and lighting (night) conditions. Other assumptions can be made in finding useful sets of capabilities for Demons. These assumptions arise from the intended roles or uses of Demons or TEARS and could include Demons which replicate tanks or are specifically intended for offensive operations. None of these assumptions were explored in our analyses. Future study

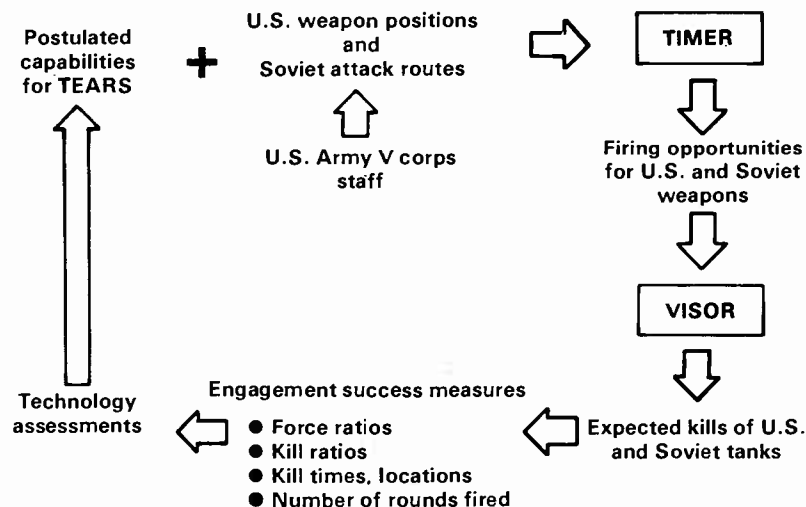


Fig. 10b — TEARS capability analysis methodology

should consider alternative assumptions before TEARS operational concepts or Demon designs are developed.

An example of the results of TEARS engagement analyses is shown in Figs. 11a-c. In this example the tank systems, alone and augmented with Demons, of a defending U.S. force are analyzed separately in terms of engagement success against outnumbering Soviet forces. The percent of surviving U.S. defending and Soviet attacking forces are related graphically to the initial force ratios. The battle begins when the attacking force closes to about 4 km from defender positions. Terrain interference with line of sight and time in view prohibits nearly all engagements beyond this range for the particular scenario area. The battle is stopped when the attacker closes to a range of about 1 km or a one-to-one force ratio is reached. This artifact forced more careful examination of longer range engagements and set the stage for investigating the various tactical options augmented tank systems have at shorter ranges.

The analytical results using current (unaugmented) U.S. tank systems are presented in Fig. 11a. The basic assumption responsible for these results is the predicated effective engagement range limit for U.S. tank guns, 2.5 km. The circles indicate an initial force ratio of about three to one, a force ratio which typically represents the capabilities of the prepared defender. At an initial force ratio of three to one the U.S. force loses over 60 percent of its tanks while reducing the Soviet force by about 20 percent. The battle is stopped at 1 km, as indicated, a range at which the defending tank force fire is highly effective.

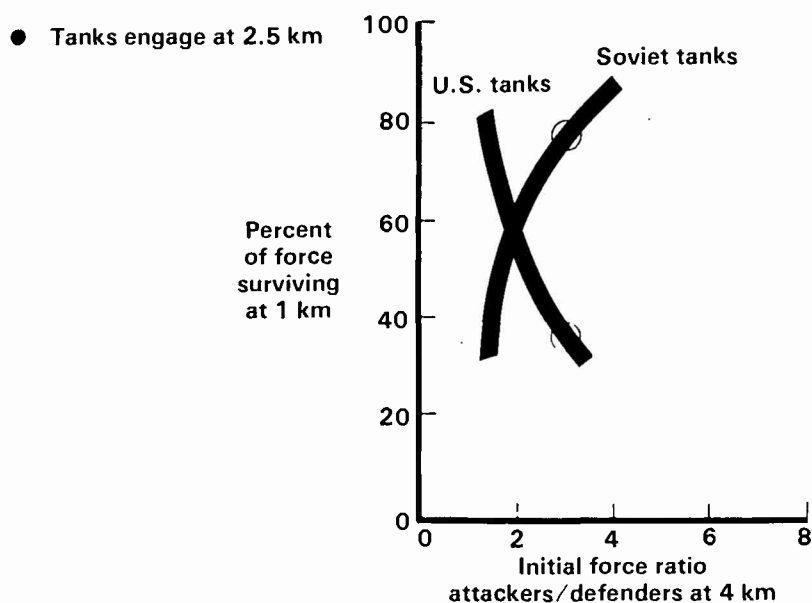


Fig. 11a — Example of TEARS capability analysis

When each U.S. tank is augmented with one Demon, a new set of curves emerges, as shown in Fig. 11b. Here, due primarily to the Demon longer range acquisition and engagement capabilities, the results shift favorably (for the defender) to higher initial force ratios. The circles on this set of curves indicate an initial force ratio of about six to one for the Soviet attackers--thought to be close to Soviet doctrine for readying attacks against prepared defenders. The augmented U.S. tank force expends about 60 percent of its force to destroy about 80 percent of the Soviet force. While this loss would be a high price to pay in U.S. tanks to achieve probably intolerable attrition to the Soviet force, the analysis shows practically no loss of U.S. tanks (Fig. 11c). Nearly all U.S. force losses are Demons. Few U.S. tank crews were lost in these simulated battles.

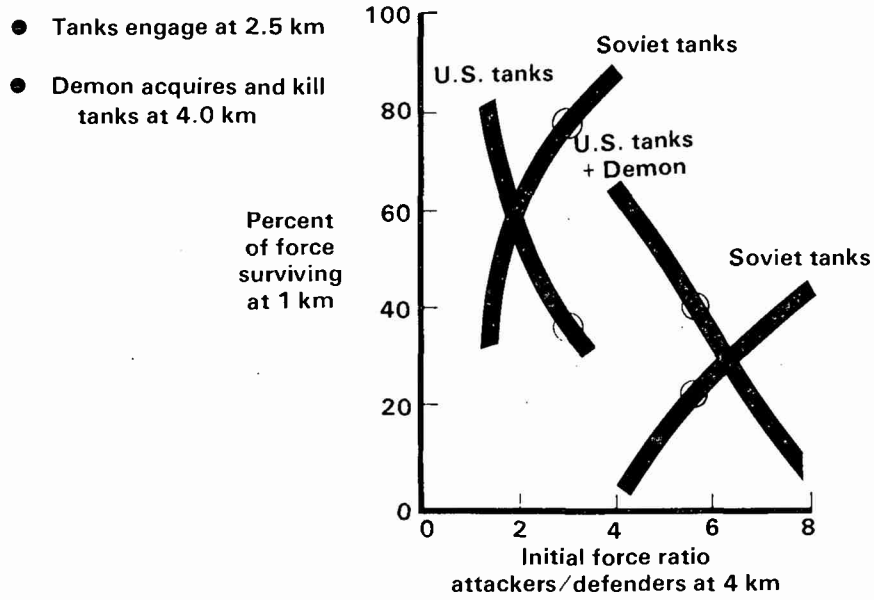


Fig. 11b — Example of TEARS capability analysis

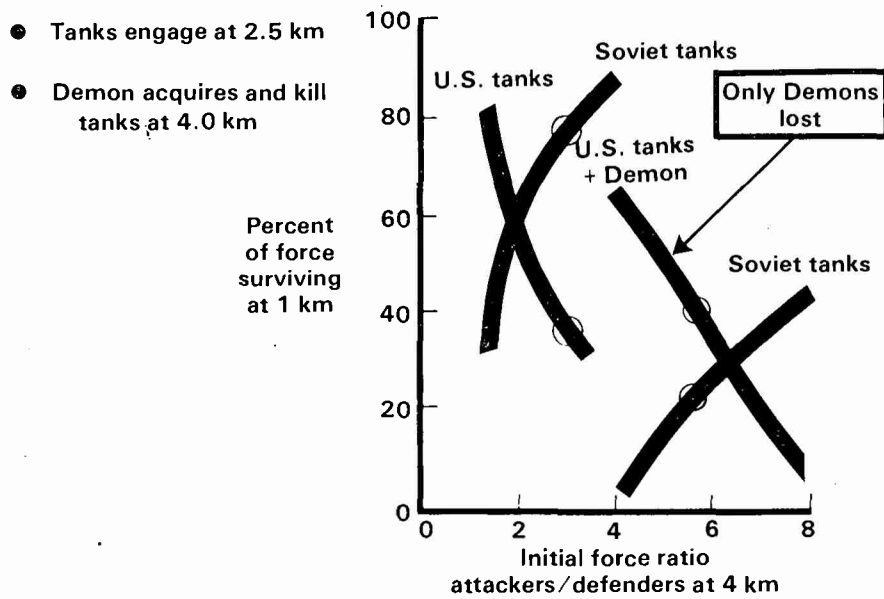


Fig. 11c — Example of TEARS capability analysis

The primary cause for the increased effectiveness of the augmented tank force is the long range target acquisition and engagement capabilities attributed to the Demon. The augmented tanks remain under cover and concealment while engaging the advancing attacking tanks through the more forward positioned Demons. The augmented tanks thus seldom come under fire from the Soviet tanks and under the engagement rules are not detectable unless their main gun is fired. The Demons, however, are a serious threat to the Soviet forces and become priority targets for the Soviet weapons. Up to this point, the close range battle (engagements at less than 1 km) has not been considered. The augmented tanks, as discussed previously, have several tactical options at closer ranges, including disengagement. Study of these options as well as Demon close range effectiveness awaits future research.

The TEARS engagement analyses raise a number of questions ranging from operational concepts for augmented tank forces to possible Soviet countermeasures against such forces. Neither these concepts nor their countermeasures have been investigated in much detail, but some comments on countermeasures are appropriate.

Possible Soviet countermeasures are listed in Fig. 12. These countermeasures presume that the Soviet forces would use resources at hand to counter TEARS and not develop specific new countermeasure systems. Some of the more pertinent aspects of the countermeasures problem for TEARS are also shown in Fig. 12.

Soviet attack helicopters might be an effective countermeasure against the TEARS system. Attack helicopters operating at higher than usual altitudes might be able to find and engage augmented tanks.

<u>SOVIET TACTICAL OPTIONS</u>	<u>RELATED RESEARCH ISSUES</u>
● Attack helicopters	● Signature of augmented tank
● ECM	● Demon attrition vs. augmented tank attrition
● Artillery	● Demon redundancy vs. expendability
● Infantry assault teams	

Fig. 12 — TEARS potential countermeasures and related research issues

However, this potential countermeasure faces several problems. First, attack helicopters prefer to operate at lower altitudes to reduce their exposure to ground fire rather than at the high altitudes required for wide area air search. Second, the Demon target acquisition and engagement system would probably be able to effectively engage helicopters. Third, Demons could be designed and operated so that even in the event of the demise of the augmented tank, they could be managed by other tanks or change to their autonomous engagement modes.

The TEARS system would have, of course, some vulnerabilities to electronic countermeasures (ECM). Its major susceptibility to ECM would probably be the communication links between the augmented tank and its Demons. Since the Demons are intended to have a high degree of autonomy, this link should be minimal in its electronic dimensions and use. The Demon sensors and weapons would probably be as susceptible to

ECM as are similar subsystems on other platforms. Radar transmitters can be designed and operated so that they are difficult to counter. The vulnerability of automated unmanned ground systems to ECM, however, remains an open question, awaiting TEARS designs and operational concepts before further resolution.

Demons could be lightly armored in selected places to reduce their vulnerability to artillery fragments and small arms rounds. Newer composite armor materials can probably provide this protection without inordinate tradeoffs in overall size and weight. Low center of gravity designs could be employed to lessen Demon vulnerability to blast effects. The Demon design goal might be a blast vulnerability no more than two to three times that of a current tank. Terminally guided artillery rounds could prove to be a serious threat to Demons, particularly if Demons can be readily detected. It is expected that Demons would be no more vulnerable to guided or unguided artillery than similarly sized vehicles with crews.

Infantry assault teams, specifically organized and equipped to find and attack Demons, seem at first glance to be an effective countermeasure. Yet, the basic premise of the TEARS concept must be borne in mind, i.e., the TEARS represents an augmentation of one member of the combined arms team. The TEARS does not replace any combined arms team member. The infantry protection afforded to tanks would be available to the TEARS system. Whether TEARS would require additional infantry to afford the same level of protection provided current tank systems is an open question. Again, Demon designs and TEARS operational concepts are needed before we can more fully explore the issue of TEARS/Demon vulnerability to infantry assault.

Other countermeasures might include some specifically developed by the Soviets to counter TEARS, perhaps even an unmanned, automated anti-TEARS system. Again, further information regarding TEARS operational concepts is required to delve further into the entire countermeasures issue.

The research issues related to the development of TEARS operational concepts listed in Fig. 12 are not exhaustive or even a selection of the more important aspects. The list does indicate some of the factors which we found difficult to deal with in our brief study.

Both Demons and augmented tanks will have signatures in various spectrums. The signatures for the augmented tank in the infrared and acoustic spectrums can be particularly critical since the tank would be trying to remain concealed in certain TEARS engagement modes. The data needed to study this issue must come from field experiments and could strongly influence both Demon designs and TEARS operational concepts.

The potential loss of the augmented tank and the associated problem of what to do with its Demons raise a variety of questions. Solutions range from providing every tank with the capability to manage any Demon to having Demons activate their autonomous mode under certain conditions signaled by communications with their augmented tank. Field tests of a TEARS testbed or simulated system will be required to resolve this issue.

A question that arose frequently in our TEARS capability analyses concerned the number of Demons assigned to each augmented tank. The comparative effectiveness, including survivability, of a TEARS system with one Demon having x missiles, or two Demons each having $x/2$

missiles, and so on, was not investigated. At the center of this question is the tradeoff between Demon redundancy and expendability. Limiting system capacities such as the number of Demons which can be simultaneously managed by a single tank crew or the warhead size required for each missile will determine some of the conditions for resolving this issue.

Several major technologies relevant to the TEARS system concept are listed in Fig. 13. Some of these technologies, in particular those which lead directly to engagement capabilities, were assessed by examining specific technology developments. A deliberate attempt was made to determine the relative availability of selected technologies (relative in the sense of the technology being lacking, developing, or abundant). The principal approach in these technology assessments was to find and evaluate ongoing and directly applicable technology or system development programs or projects. This approach identified several system/technology development programs whose progress supported the conclusion that the necessary technologies are available now or soon will be for the various TEARS subsystems.

In each of three areas of technology--distributed automated controls, data links, and remote management--we have suggested TEARS capabilities which appear to require specific technology developments. Although these developments appear possible and practicable, more extensive technology assessments are required.

One area of great concern is the integration of the various technologies inherent in the Demon. The technical risk involved in all integrations is substantial and in this case should be considered high risk. Once again, the extent of the risk will be better understood when

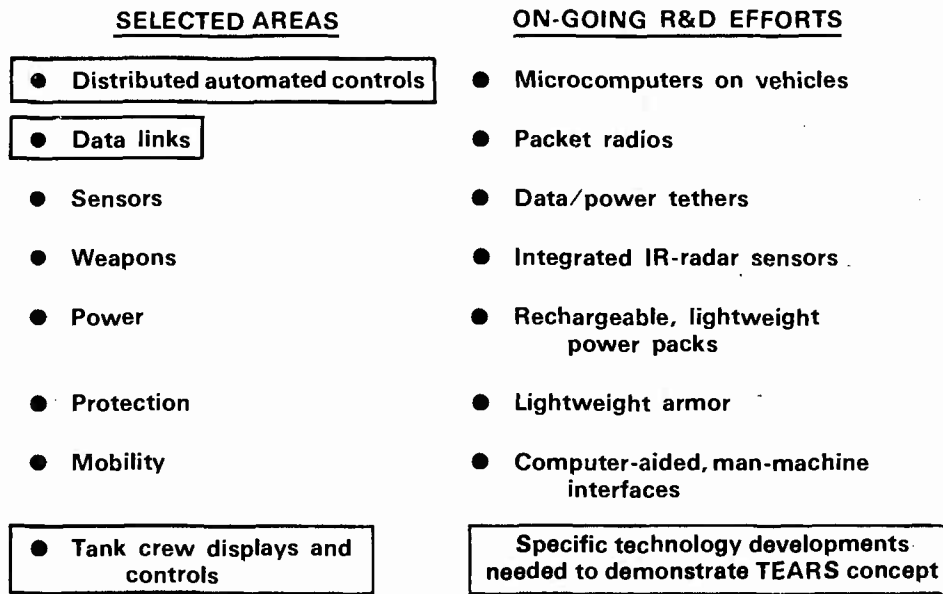


Fig. 13 — Technology areas

specific designs and techniques to achieve various system capabilities are proposed and examined.

The study of TEARS affordability, i.e., what drives Demon costs, requires the use of a strawman Demon to identify module dimensions for cost estimates. For this purpose and to be consistent with various Demon characteristics and capabilities already postulated, we considered a mobile Demon with a 3000 or 6000 lb gross weight, an 8 to 10 missile module, an integrated IR/mm wave radar sensor module and hybrid propulsion (electric primary with small diesel or gasoline engine for auxiliary power and electrical system recharging). The estimated weight budget for either Demon is shown in Fig. 14. The mobile platform weight includes chassis, power plant, controls, and armor. These weights are based on commercially available, wheeled, low ground pressure chassis and motor components; current microcomputer packages, available

actuators, and lightweight armor materials. The weapon module weight is based on the current TOW system, with each TOW credited with a launcher. The weight of the sensor module is estimated from the projected weight of current vehicle mounted integrated radar-IR systems. Each Demon version has a small excess weight allowance. Conservative approaches have been taken for these weight estimates in at least two instances. First, the Demon has been hypothetically fabricated by putting together various subsystems and modules designed for other purposes, i.e., no credit has been given for weight savings possible by integrated designs. Second, lighter missile modules (or more missiles per module), more characteristic of the kinds of homing missiles discussed earlier, will soon be available. These newer missile systems, exemplified by the DARPA TANKBREAKER development, could also provide less expensive missile modules. The external cargo weight limit for the U.S. Army CH-60 (Blackhawk) helicopter (about 7000 lb) was used to limit Demon gross weights.

The management or command console required in the augmented tank is considered to be included in the controls component weight of the Demon mobile platform. Since the TEARS design philosophy is based on not encumbering the augmented tank, the tank console would be small and light.

Demon platform costs appear to be in the range of several to a few dozen thousands of dollars. A missile module (based on TOW cost estimates) and a dual-sensor module would each cost about \$100,000. The estimated total procurement costs for a strawman Demon appear to be about \$250,000 (FY 1980 dollars).

	1		2
Mobile platform	3000#		1300#
Chassis and motor-----	2000		1000
Controls-----	200		100
Armor-----	800		200
Weapons module	2100		1400
10 missiles @ 60-----	600	(8x50) 400	
10 launcher(s) + @ 150	1500	(8x120) 960	
Sensor module	500		300
Radar assembly-----	350		300
IR imaging assembly-----	150		100
Other-----	400		100
	<u>6000#</u>		<u>3000#</u>
Blackhawk cargo limit = 7000#			

Fig. 14 — Estimated weight budget for Demon

The major cost factors for the Demon are the weapon and sensor modules. Either module could have the greater cost for a particular design. Current missile developments suggest that missile module costs could be reduced substantially (over TOW missile modules). Demons with smaller weapon modules (or fewer missiles), less capable sensor modules, or without mobility could have considerably lower costs.

To place some meaning to this Demon cost estimate, the Demon was compared with a similar current system which has a crew. The analogous system, the Improved TOW vehicle (ITV, M-901) consists of a TOW launcher (and several missiles) mounted on an M-113 (armored personnel carrier) chassis and has a four-man crew. Estimated procurement costs for the ITV system range from \$350,000 to \$380,000 in FY 1980 dollars. The strawman Demon is estimated to cost less than the ITV to procure, but its development costs would probably surpass those of the ITV. The ITV

seems to be more versatile than the Demon, although direct effectiveness comparisons have not been considered. A major cost saving advantage for the Demon arises from the absence of crew costs, as the augmented tank crew is counted in the tank costs. The Demon affordability estimate is summarized in Fig. 15.

Although it is too early to be concerned with discrete designs for the Demon, the composite strawman used for cost estimate purposes was translated into a scale model with selected operative features (Fig. 16). This model, designated Demon I, was used to explore some design and mobility considerations. Demon I features include an electrical umbilical (tether)[3] for propulsive power and control, a low ground pressure wheeled chassis for suspension and rough surface travel, skid steering (differential power application to either side set of wheels) for turns and azimuthal alignment of missile tubes, and a scanning

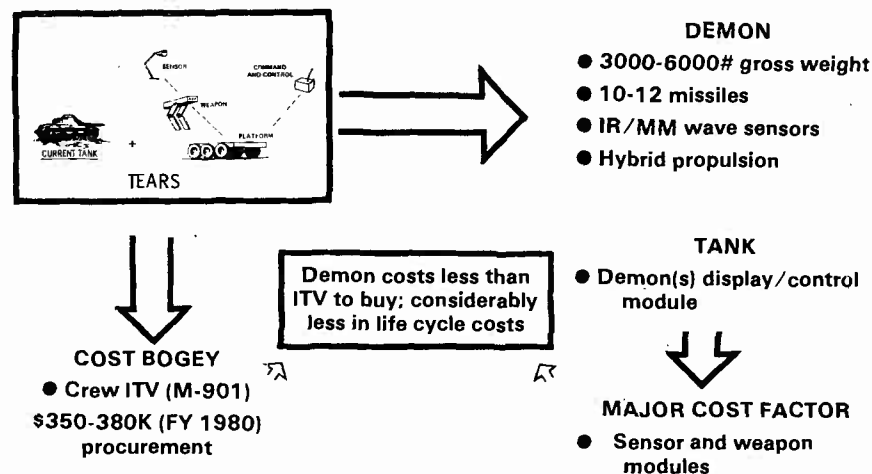


Fig. 15 — Affordability issues

[3] Tether was used for model purposes only and is not suggested for full scale development.

sensor head that can be elevated. This Demon model is approximately one-tenth scale size. Other model designs are possible within the broad design guidelines developed in our study. Demons with gun systems or tracks have not been investigated, but should be in future study efforts.

A preliminary evaluation of the TEARS concept was made using a methodology developed by the U.S. Army Armor Center to identify the possible impacts new technological developments could have on U.S. armor forces. This methodology relates the TEARS concept to various capabilities required in armor system and force operations. The results of evaluating the TEARS concept are shown in Fig. 17. It is difficult to comment on some of these capabilities without developed operational concepts. Also, some of the capabilities introduced by TEARS have not been accounted for in current methodology concepts. It is clear,

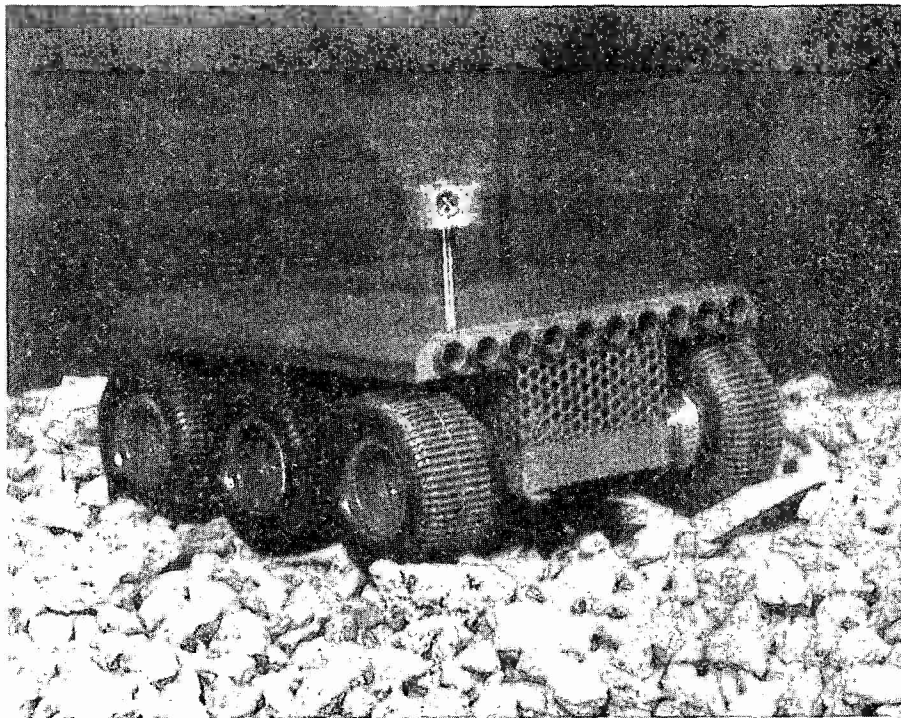


Fig. 16 — Demon I model

however, that successful implementation of the TEARS concept could provide improvements in nearly all of the listed capabilities.

Some major characteristics of near term distributed combat vehicle systems concepts are summarized in Fig. 18. These concepts represent a new approach to the use of unmanned ground vehicle systems, i.e., by using remote management, not remote control, of highly automated subsystems. In the near term period distributed combat vehicle systems could consist of current combat vehicles augmented with one or more unmanned target acquisition and engagement subsystems. The basic value of these concepts is increased firepower/manpower ratios, firepower mobility, and survivability for mechanized forces.

The augmented combat vehicle need not be a tank but could be any vehicle equipped with remote management capability. A new vehicle could

Capability	Improvement score	Comments
Engage enemy targets	++	Wider, longer fields of fire; high rates of target servicing
Obtain/comm. info.	+	Wider, longer fields of view; different sensors; integrated sensors
Highly mobile opns	?	Reduce tank static defense role; not adaptable to rapid offensive movement
Continuous opns	+	Autonomous mode; unmanned
NBC opns	+	Auto. mode; system spread over larger area; unmanned subsystems
All vis./climate opns	+	Variety of sensors; integrated sensors
High materiel readiness	?	Easy to store, activate, transport Demon; more complex system, readiness(?)
High training readiness	?	More training for some of tank crew; training with simulators
Survive attack	++	Target array for enemy to kill

Fig. 17 — Preliminary evaluation of TEARS concept

<u>ARE</u>	<u>ARE NOT</u>
● Concepts to extend combat vehicle capabilities using unmanned subsystems	● Remotely controlled vehicle concepts
● Concepts to augment the combat vehicle systems of the combined arms team	● Concepts to replace any system of the combined arms team
● Concepts to increase the firepower/manpower ratio of mechanized forces	● Concepts to decrease armor force manpower

Fig. 18 — Summary I

be developed for this purpose, as illustrated in Fig. 19. In this case the crewed management vehicle (Demon II) is similar to the unmanned target acquisition and engagement vehicle and, if desired, could have an almost identical external appearance. The management vehicle, probably containing a two-man crew, would be as transportable by cargo aircraft or helicopter as its managed vehicles. There are other possible adaptations of distributed weapons systems concepts. The simplest version may be a distributed artillery or air defense system concept in which relatively few personnel manage several automated, mobile gun, or missile platforms.

Distributed weapons systems concepts are in line with many warfare doctrines (Ref. 9) and trends (Ref. 10) currently being promulgated or proposed by U.S. Army training, doctrine development and user commands.

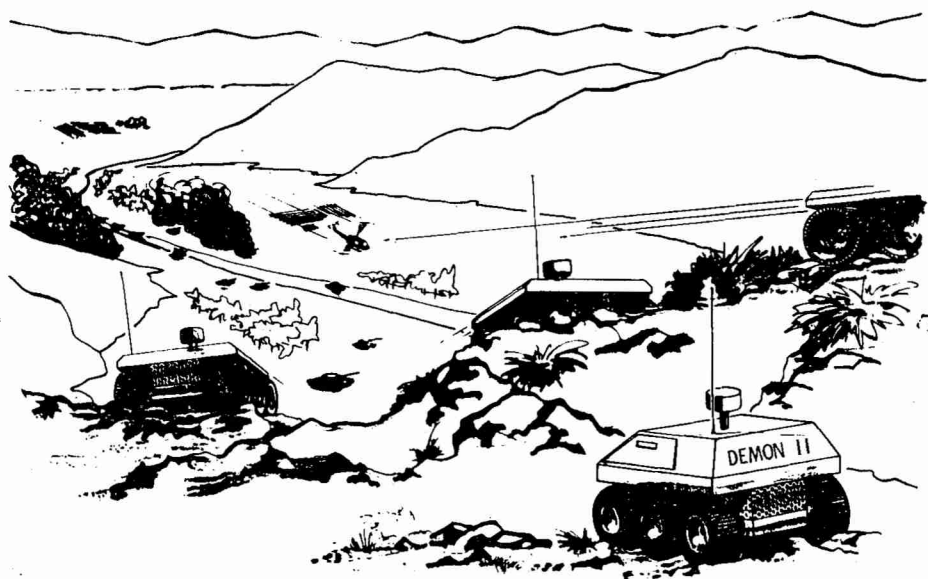


Fig. 19 — Distributed combat vehicle system concept
(Demon II)

VI. FINDINGS AND RECOMMENDATIONS

The initial conclusions of our research are summarized in Fig. 20. Although distributed combat vehicle systems are new and revolutionary concepts, they might be realized by using unmanned subsystems to augment the capabilities of current vehicle systems. In addition, a program to investigate augmented systems would provide invaluable information for developing alternative future combat vehicle system designs. Our analyses indicate that unmanned augmenting target acquisition and engagement subsystems could change the classical ideas of combat vehicle firepower, firepower mobility, and survivability and greatly expand each of these generic capabilities. An advanced technology development and demonstration program is required to further resolve system feasibility, effectiveness, and affordability questions. A joint DARPA/Army integrated technology program is suggested.

A proposed DARPA/Army TD&D program is outlined in Fig. 21. The approach suggested here is the use of successive testbeds to minimize technical risk and better utilize research resources. The Phase I effort (concept development) requires an additional year of study to obtain sufficient data for prototype testbed design and identification of testbed experiments. The prototype testbed phase would consist of experiments with a Demon testbed flexible enough to simulate several Demon configurations. The TEARS testbed phase would involve more than one Demon. The last phase of the program would be the design, fabrication, and demonstration of a TEARS system suitable for various field test efforts. Major decision points preface each phase to allow

- **Distributed combat vehicles systems are new and revolutionary concepts**
- **These systems could provide significant increases in armor force**
 - **Firepower**
 - **Survivability**
 - **Mobility**
- **Integrations of advanced technologies is major technology question**
- **Joint DARPA/Army technology development and demonstration program needed to demonstrate feasibility and answer major questions of potential effectiveness and affordability**

Fig. 20 — Summary II

adequate consideration of program progress and anticipated costs.

Current progress within the concept development phase of the proposed TD&D program is indicated in Fig. 22. The Rand research effort has reached the concept statement area. Further research efforts should include participation by interested Army R&D and/or user agencies or commands to insure coordinated development of operational concepts and their technological implications.

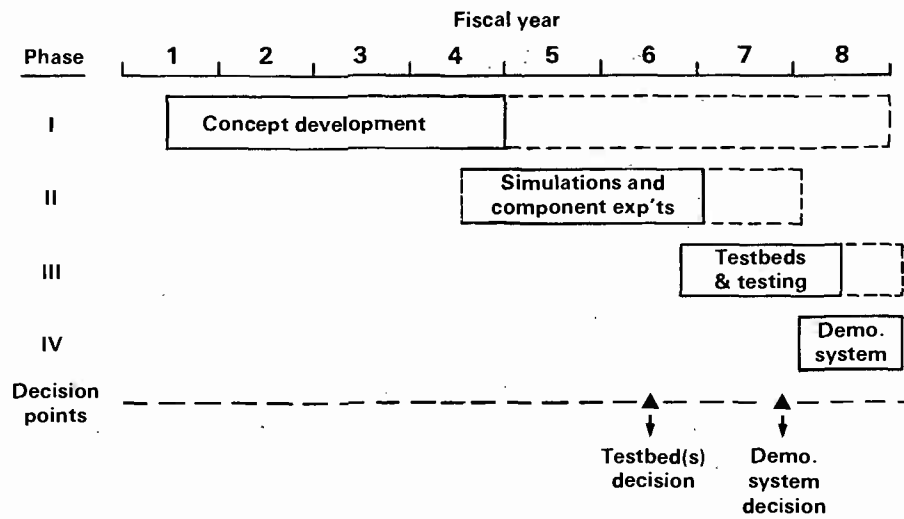


Fig. 21 — Proposed DARPA/Army TD&D program

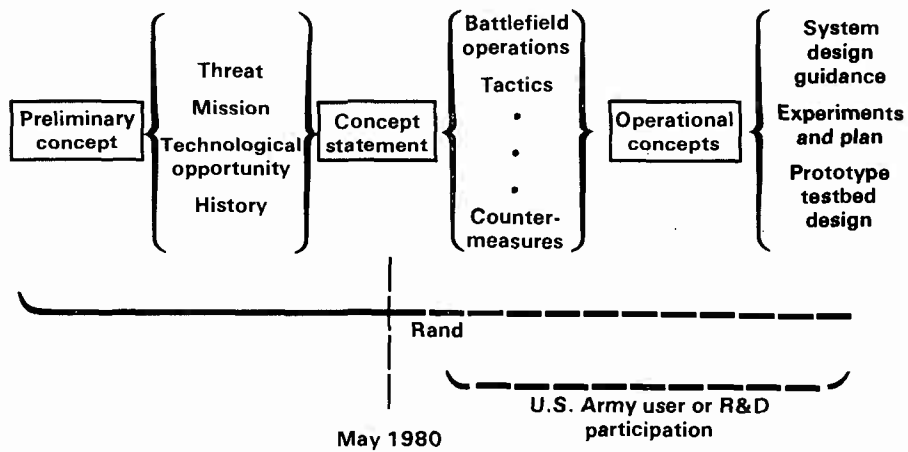


Fig. 22 — Phase I efforts

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